

Title:

Direct Observation Detonator Operation (DODO)

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January 10, 2001

I. Introduction

For more than thirty years, The United States Nuclear Weapons Program has used Rotating Mirror Cameras (RMC) to gage the temporal difference between detonators. Several \$250K RMCs manufactured by Cordin are presently used at Los Alamos National Laboratory for this purpose.

The Los Alamos National Laboratory is responsible for validating all detonators presently used in any United States nuclear weapon. This validation program has evolved to include the ability to measure detonator timing to nano-seconds resolution. This capability is critical in determining the readiness of all United States nuclear weapons.

In this report I will discuss:

1. How the Los Alamos National Laboratory presently tests detonators.
2. The evolution of the Direct Observation Detonator Operation (DODO).
3. DODO's future impact on detonator certification.

The Detonator Science detonators Group of the Dynamic Experimentation Division at the Laboratory presently perform detonator validation. Approximately three fulltime staff and three fulltime technicians are required to support this certification process. Numerous other capital resources are also required toward this process. Over the last few years, an increasing number of mandates from the Department of Energy, State Environmental Agencies and the Los Alamos National Laboratory have burdened the detonator certification program resources with minimal increases in the budget for performing this critical national responsibility. Los Alamos National Laboratory is always interested in any technology that can reduce resource requirements for this certification process.

II. Current Detonator Certification

Over the past 50 years, hundreds of detonators from every production run were placed in storage. Every year a number of these detonators are removed from storage and tested. These detonators are first physically inspected then transported to a special firing facility for functional testing.

The firing facility is a major capital resource, which includes a building with three main sections and a bunker for explosives storage. The main building includes an outdoor firing area similar to a garage with rollup doors and special reinforced concrete walls. Detonators are fired in the outdoor area. Thick steel reinforced walls with a small glass port separate this area from a Rotating Mirror Camera room. This room is also reinforced and isolated from the main instrumentation room. The RMC uses a small rotating mirror made of beryllium. This mirror is driven by a gas turbine and will rotate at twenty thousand revolutions per second during detonator tests. This provides a 10 mm/us writing speed on the film. The potentially explosive nature of this rotating mirror prevents anyone from being in the room with the camera during camera operation. All operational personnel are required to remain within the instrumentation and control room during tests. The instrumentation and control room consists of all computers and digitizers

necessary for recording data. Furthermore, all camera controls and detonator firing electronics are operated from within this area.

The following procedures are indicative of the sequence required to test a single pair of detonators.

1. The test procedure begins with closing the area to all non-authorized personal.
2. Detonators are then mounted on a firing pedestal.
3. The RMC is aligned and focused and film is loaded.
4. A static exposure is preformed that yields an image of the detonator on the film. This guarantees the camera focus.
5. Sirens begin to alert personal of an impending test.
6. All electronics are tested. This test is called a ring-down.
7. The RMC is spun up to 2500 rpm. When the appropriate rpm is achieved, a signal is sent from the RMC to fire the detonators. The light from the exploding detonators is captured and transferred via the rotating mirror to film. A series of optical pulses representing calibrated time marks are also recorded on the film. These time marks are referred to as fiducial timing marks and will be used to compare detonator timing.
8. The film is removed from the camera and processed much the same way all photographic film is processed.
9. The operation is then repeated for the next set of detonators. A single test can be repeated about every hour.



Fig. 1 Cordin Rotating Mirror Camera.

The film is transported to a technician who will place the film under an optical comparator that expands the image and compared with the fiducial marks and the image recorded.

Only the temporal information recorded on film is of importance in resolving detonator timing. If light could be captured with sufficient amplitude and recorder directly to digitizers, much of this process could be streamlined and resource loading dramatically reduced.

III. The evolution of the Direct Observation Detonator Operation (DODO).

A series of tests was preformed to determine rise time and optical signal level captured and recorded at detection time. Ten detonators were directly attached to a graded index lens (grin lens) that is coupled to an optical fiber. An aluminum-silica-fluoride compound (SALT) is applied to the surface of the detonator to help generate a brighter instantaneous light flash upon the arrival of the explosives shock wave. Three meters of optical fiber conduct the light to a Tektronix optical to electrical converter (P6701). The signal was recorded on a Tektronix TDS784A digitizer. Greater than two milliwatts peak of optical power was coupled to the optical detector. Sufficient light was captured to saturate the detector. Less than one fifteenth of the total light was captured because the grin lens is 2 mm in diameter and the detonator's surface diameter is 7.62 mm diameter.

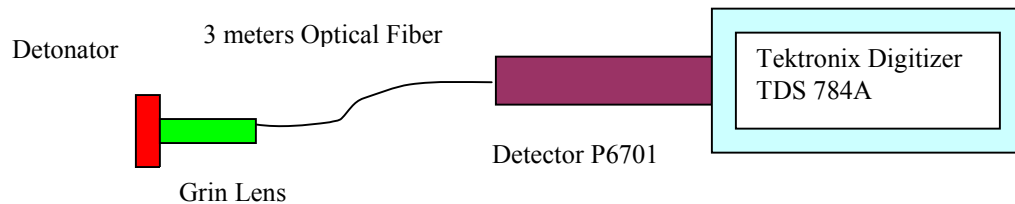
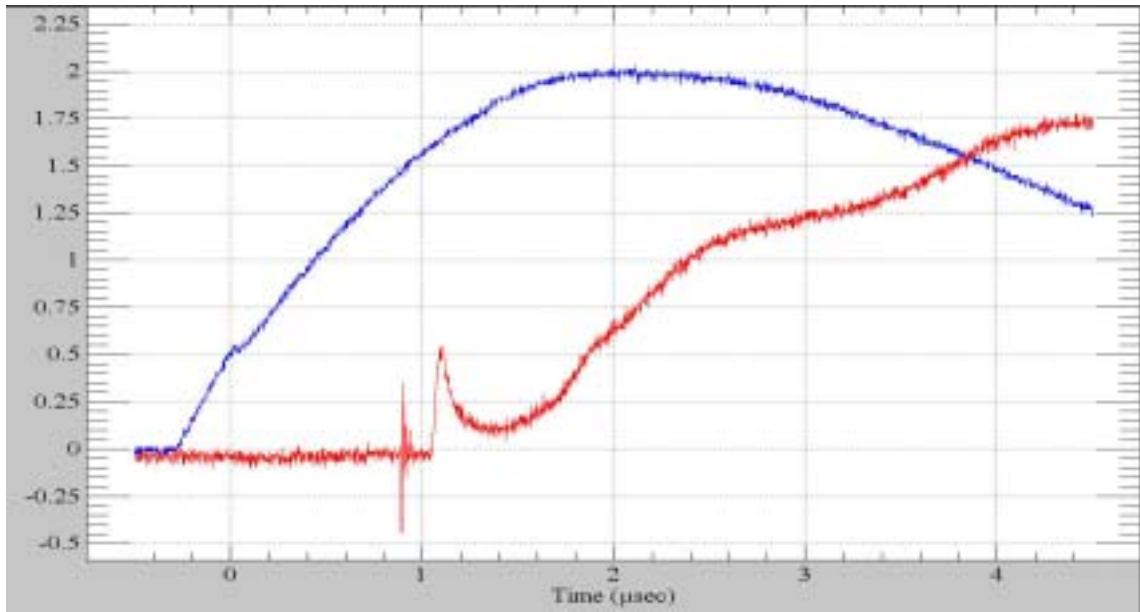


Fig. 2 Detonators to Grin Lens Experiment Schematic.

Given the hazard associated with detonators, all experiments were contained in a steel cell designed for explosive testing. This cell is fully interlocked so as to prevent any energizing of electrical equipment prior to testing. Furthermore the cell is provided with a two-inch thick glass viewing port to monitor the experiments. A half-inch thick polycarbonate panel is placed between the detonator and viewing port for glass protection.

The Signal from the optical detector was compared to the electrical current output of the Capacitive Discharge Unit (CDU).



**Fig.1 Top trace CVR(Current Viewing Resistor) at output of CDU.
Bottom trace output from Optical Detector.**



Fig.2 Grin Lens-fiber used to couple light from Detonator to Optical Fiber.

IV. Proof of Principle:

- **More than 2 mW peak of optical power can be coupled directly into optical fibers with a Grin lens-fiber attached directly to detonator.**
- **The optical signal rise time is sufficient to provide a reasonable timing resolution.**

With a measured peak power of > 2 mW and a grin lens area of 3.14 mm^2 , it may be assumed that the optical power generated at the surface of the grin lens is:

$$P/A = P/\pi r^2$$

P is the optical power. A is the area and r is the grin lens radius. The coupling efficiency stated by manufacturer is 75% to 85%. Power is then calculated with an assumed 75% coupling efficiency.

$$0.637 \text{ mW}/2\text{mm}^2 * 1.333 = 0.85 \text{ mW}/2\text{mm}^2$$

It is then estimated that the optical power coupled during detonation is approximately $0.45 \text{ mW}/\text{mm}^2$. The coupling efficiency of the grin-fiber unit was tested by injecting a calibrated light source into the fiber end of a grin-fiber unit then recapturing the light emitted with another grin-fiber lens. The measurement was compared with a one-meter optical fiber directly connected to a calibrated light source to a calibrated light detector.

Furthermore, the detonator could be described as a point source of optical power and be described as a Lambertian emitter. The fundamental equation of transfer can be applied to a Lambertian Emitter to obtain the relationship between radiance and radiant emittance for such a source. The power of the entrance pupil is the source radiance times the source area times the aperture area divided by the square of the range.

$$\text{Power} = L(A_o A_s / R^2)$$

L is the radiance. A_o is the area of the optic. A_s is the source area in this case the detonator. R is the distance from the source to a lens. Most detonators developed and used at Los Alamos National Laboratory have a diameter of 7.62 mm, which yields an area of 45.6 mm^2 . The area of the detonator divided by the area of the grin lens is a ratio of 14.52. Furthermore we have a P/A of .85 mW for the grin lens area, so $.85 \text{ mW} * 14.52 =$ approximately 12.6 mW of optical power from a detonator during detonation.

V. The Production Design of the Direct Observation Detonator Operation (DODO).

An Industrial Model “K2 Dual Port Long-Distance Microscope” was purchased from Infinity Optical Company. A zoom module was added to provide continuous magnification increase from 1x to 2.2x. A 10x eyepiece along with a 500T objective lens were add to give the unit a field of view 9.1-75 mm and working distance of 700- ∞ . The effective aperture give by the manufacturer is 38 mm.

Furthermore we can calculate the ability of the K2 to capture optical power with the same Lambertian equation.

$$\text{Power} = L(A_o A_s / R^2)$$

L is the radiance of approximately 29 mW optical power. A_o is the area of the optics which is 1134 mm^2 . A_s is the detonator area of 45.6 mm^2 . R is the distance from the source to a lens. A practical distance of 558 mm will be used in future tests so this is the distance used for calculation purposes.

In theory the K2 should be able to directly capture about 4.8 mW or 6.8 dbm of optical power.



Fig 3. The Infinity Long-Distance Microscope with Grin Lens Fiber Attached.

A grin lens was adapted to the K2 and optimized for maximum light coupling. Due to the explosive nature of the experiment, it must be contained in an explosive containment enclosure. An LED was placed at 24 inches from the K2 and the light

measured. The window and polycarbonate were placed between the K2 and the LED and measurements repeated. The window and polycarbonate added an additional 2.4 db of attenuation to the line of sight.

A combination of twenty detonator and exploding bridge wire (EBW) shots were preformed at TA-40 building 34. The light generated by the detonators and EBW's was captured at 22 in, 44 in, and 66 in. During this series of test aluminum-silica-fluoride compound (SALT) was added by hand to some of the detonators. The detonators with SALT produced a pre-light with a several nanoseconds rise time where as the light from the detonators with out SALT generally had a rise time of several microseconds.

Though the pre-light light levels are relatively lower compared to the light from the bare detonator, the fast rise time of the pre-light from the SALT could provide a much improved reference for measuring detonator "first light". Thus my focus changed from simply measuring the total detonator light to measuring pre-light generated by the SALT.

In general the total light levels from the detonator were about 100 uW (-10 dbm) whereas the pre-light level was about one forth or 25 uW (-16 dbm).

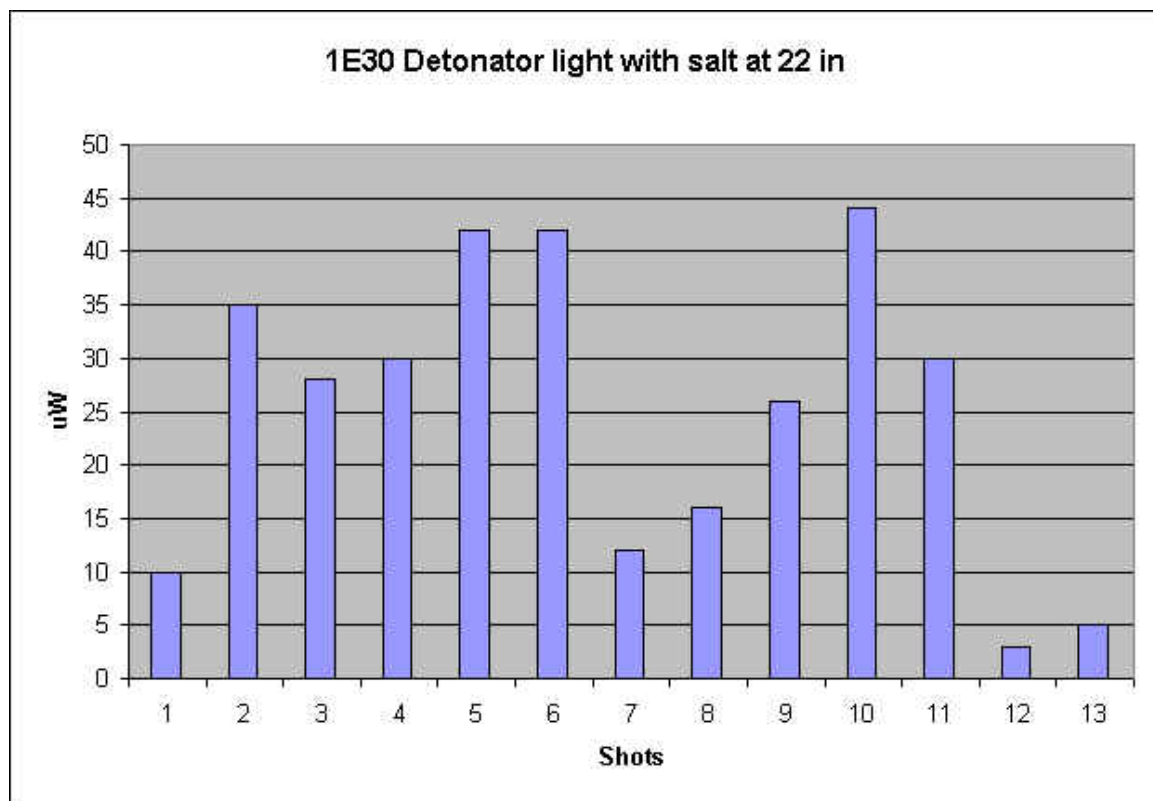


Fig. 4 Pre-Light levels from SALT.

Shot 12 and 13 were measured with a Tektronix model P 6703A optical-to-electrical detector with has a sensitivity between 1100 nm and 1600 nm. It is apparent that very little optical power is within this spectrum. Furthermore, the differences in optical power between shots one through eleven may be attributed to the inconsistent hand application of SALT to the detonator.

Conclusions:

- The total optical power captured by the K2, coupled into the grin lens, and into an optical fiber seems to be more than a factor of ten less than calculated. Some coupling losses will occur between the K2 and detector interfaces. More research into the actual losses between each interface should be pursued.
- Tests should be preformed to optimize the application of aluminum-silica-fluoride compound to the face of detonators. The application should be consistent and of the appropriate thickness and uniformity as to provide the best rise-time and light intensity.

Acknowledgments:

Special thanks to Dave Ceman for his encouragement. To Joe Ortega for the machining and assembly, and Jerry Paul for his help with proof reading this paper.

Reference:

1. Polymicro Technologies, The Book on the technologies of Polymicro, 1998, 2-3 thru 2-8
2. Wolfe, William L. Introduction to Infrared System Design, Vol. TT 24, 1996, 14-19
3. Host, Gerald C., CCD Arrays Cameras and Displays, 1996, 18-29